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FOAM-GLASS BASED COMPOSITE HEAT-INSULATING MATERIAL WITH A PROTECTIVE-DECORATIVE COATING ON THE FRONT SURFACE

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The prospects for obtaining heat-insulating foam-glass with a protective-decorative coating which will make it possible to increase the water resistance and longevity of the material as well as to improve its decorative properties are examined. In addition, such a composite heat-insulating material could find application for architectural-artistic design of modern buildings and structures.

The production of high quality heat-insulation materials is one of the most important problems of the building materials industry. Of all existing heat-insulating materials, foam-glass is most promising. Heat-insulating foam-glass, combining valuable properties such low bulk mass, low thermal conductivity, comparatively high construction strength, freeze resistance, and inflammability, is one of the best wall-insulating and coating materials for all types of building structures. Its properties make foam glass superior to most existing materials (foam concretes, polystyrene foam, mineral wool, and so forth). The strength of these materials is low and they are not decorative. Additional construction-assembly and finishing operations (SNiP II-3-79) must be performed when they are installed in buildings and structures [1 – 4].

In the present article it is shown that it is possible to produce foam glass with a decorative-protective coating on its surface.

The production of a high-quality coating depends on the optimal ratio of the viscosity, surface tension, degree of spreading, wetting power of the melt, bonding strength between the coating and the substrate, thickness and uniformity of the coating layer, and presence of gaseous inclusions in the substrate and slip.

The choice of the temperature interval for this investigation was limited by the temperature at which the foam glass starts to soften. Consequently, the investigations were performed at temperatures up to 600°C.

One of the most difficult problems to solve in the synthesis of protective and decorative glass coatings is to create a strong bond between the coating and the substrate. It is thought that the main condition is to choose a CLTE of the coating that is within 10 – 15% of the CLTE of the substrate. However, a number of coatings [5, 6] which are distinguished by stable bonding even though this condition is not satisfied do exist. Conversely, in the process of synthesizing coatings investigators often find that the coating chips even when the CLTE of the coating corresponds to that of the substrate [6].

The coating composition for this investigation was chosen on the basis of the CLTE of foam glass.

It was established experimentally that the CLTE of foam glass (see Fig. 1) lies in the range $(99 - 105) \times 10^{-7}\ K^{-1}$, and according to calculations performed using Appen's

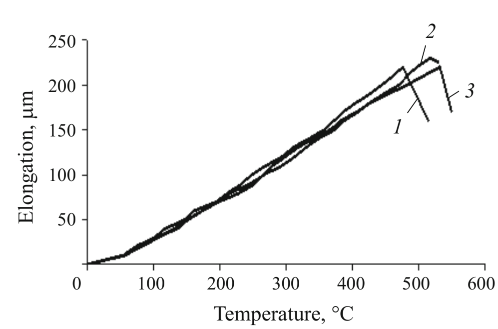

Fig. 1. Dilatometric curves for determining the CLTE of foam glass samples. The numbers of the curves correspond to the sample numbers.

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TABLE 1.

Frit	CLTE, 10^{-7} K^{-1}	Melting temperature, °C
Al 1	153.670	329
Al 2	166.245	443

TABLE 2.

Frit	Surface tension, mN/m		Wetting angle, °
	experimental	computed	
Al 1	312.7	224.85	45
Al 2	348.6	269.89	46

method the CLTE of the initial glass is 90×10^{-7} K^{-1}. Therefore, the CLTE of the coatings must lie in the range $(75 - 105) \times 10^{-7}$ K^{-1}, which corresponds best to the conditions for choosing a decorative-protective layer for the coating.

Investigations to obtain a high-quality coating were conducted in several directions.

The first direction was the use of standard coating compositions. Standard enamel coatings for steel corresponded to the criterion chosen. The CLTE of the coatings was $(80 - 130) \times 10^{-7}$ K^{-1}. Such coatings belong to the system $Na_2O - B_2O_3 - SiO_2$ (composition of the standard enamels ÉSP-117, ÉSG-26, ÉSG-52, and others). However, it was found that the melting temperature of the enamels which are used for steel exceeds 600°C (660 – 740°C), so that such enamels had to be rejected.

Subsequent investigations were conducted with aluminum enamels Al 1 and Al 2, since they possessed the required temperature for the onset of melting and spreading. Appen's method and the computer program Metod Appena 3 were use to calculated the CLTE of the frit for these enamels (Table 1).

As the data in Table 1 show, the CLTE of the aluminum enamels are much higher than the CLTE of the substrate (foam glass), but the coatings with CLTE different from that of the substrate likewise can give a high-quality bond. Consequently, the mix for aluminum enamels fired at low temperature had to be adjusted.

The surface tension and the wetting angle of the aluminum enamels were determined in order to choose the composition (Table 2).

The enamel Al 1 possesses a lower softening temperature than the enamel Al 2 and spreads better over the substrate, and its wetting angle is smaller.

The technology generally used in enameling was used to obtain coatings for foam glass. The frit was milled until it passed through a sieve with 10,000 openings/cm^2. Glass cullet and bentonite clay were added to the frits to improve the quality of the coatings. The dry (powder) method and casting were used to deposit the coatings.

The samples were dried at 110×10°C and fired in the temperature range 350 – 550°C with step 50°C and held at the maximum temperature for 10 min.

The composition No. 3 based on the Al 1 enamel was chosen on the basis of investigations of the dependence of the coating quality on its content of the frits, glass cullet, and clays chosen. This composition contains sheet-glass cullet and Al 1 enamel in the ratio 1 : 99 with 1 – 2%[2] bentonite clay added. A high-quality coating without any visible surface defects was obtained at 550°C. The composition of coating No. 3 can be recommended for deposition on a foam-glass surface by the casting method.

The second direction for obtaining coatings is to use liquid glass together with glass cullet. We used glass cullet with different composition: green and brown containers, crystal, medical and sheet glass. Liquid glass was introduced into the slip in amounts ranging from 10 to 50%. At liquid glass content 10 – 30% separation of the top layer was observed. For this reason, subsequent studies were performed with liquid glass content 40 – 50%.

Of all compositions investigated, a high-quality matte coating on the surface of foam glass was obtained using composition 17, consisting of sheet-glass cullet and liquid glass in the ratio 100 : 50. The coatings were deposited by the casting method, dried at 100°C for 12 h, and then fired at 550°C.

The third direction is to use slags from ferrous metallurgy to decrease the cost of the coatings.

Taking account of previous work on the use of ferrous-metallurgy slags in the production of foam glass [7 – 9], slags from the Novolipetskii Metallurgical Works (NLMW) with the following chemical composition were chosen (%): 36.78 SiO_2, 18.20 Al_2O_3, 36.78 CaO, 5.05 MgO, 7.69 FeO_{gen} and sheet-glass cullet. It was assumed that this composition will possess adequate viscosity to obtain strong sinter with an even surface on the glass foam. The following ratios of slag and cullet were chosen: 40 : 60, 35 : 75, 30 : 70, and 20 : 80 (Table 3).

The calculation of the CLTE of the chosen compositions by Appen's method showed that the values were close to the CLTE of the substrate and, therefore, the coatings should have a strong bond with the substrate.

Coatings CLTE

Coating composition	CLTE, 10^{-7} K^{-1}
18	84.890
19	85.785
20	86.475
21	89.091

The compositions 20 and 21 possessed high porosity, and their apparent density was 560 and 430 kg/m^3, respectively.

[2] Here and below — content by weight.

TABLE 3.

Composition	NLMW slag : cullet ratio	Content, wt.%					
		SiO_2	Al_2O_3	FeO_{gen}	MgO	CaO	Na_2O
18	40 : 60	56.69	8.21	3.08	3.81	19.87	8.34
19	35 : 75	58.81	7.42	2.79	3.73	18.56	8.69
20	30 : 70	60.68	6.63	2.33	3.64	17.24	9.48
21	20 : 80	64.40	5.01	1.58	3.45	14.73	10.83

TABLE 4.

Material	Coating microhardness, MPa	Compression strength, MPa, with load direction	
		perpendicular to the plane of the front surface	along the from surface
Foam glass with coating	6688	2.20	6.24
Foam glass	–	1.60	5.60

It was found that when using the compositions 18 and 19 it was necessary to accelerate the firing process or heat-treat the slag beforehand. One way to accelerate the sintering process without changing the chemical composition is to compact a cover layer consisting of slag and cullet. These compositions were compacted in a hydraulic press at pressures 15, 20, and 30 MPa.

The preliminary compaction made it possible to obtain a high-quality coating on the surface of the foam glass using composition 19. The main mechanical properties of a coating with composition 19 were determined (Table 4).

A comparative analysis of the results showed that the material obtained is stronger than foam glass, i.e., the deposition of a coating makes it possible to obtain composite materials with greater strength.

In summary, it has been confirmed experimentally that an effective heat-insulating composite material can be obtained on the basis of foam glass with a coating. This makes it possible to decrease the expenditures on additional protection of the surface of foam glass from atmospheric precipitation by means of a facing and to expand the aesthetic and decorative properties of foam glass, making it possible to use foam glass more extensively in construction and architecture. The recommended coatings for obtaining a composite heat-insulating material with a protective-decorative coating on the front surface are the composition 3 based on standard enamel with the addition of glass cullet and clay, 17 (sheet-glass cullet and 40 – 50% liquid glass), and 19 based on slag from the NLMW and glass cullet. A coating based on slag strengthens the foam glass, makes it possible to salvage some wastes from ferrous metallurgy, and is characterized by a lower cost than the compositions 3 and 17 but it is inferior to the latter with respect to decorative characteristics.

The use of foam glass makes it possible to stabilize the thermophysical characteristics (resistance to heat transfer) of safety structures for several years. The material obtained is ecologically clean, fire-resistant, and long-lasting.

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